(19) **United States**

(12) **Patent Application Publication**

OKUDA et al.

(10) **Pub. No.: US 2024/0128169 A1**

(43) **Pub. Date: Apr. 18, 2024**

(54) **SEMICONDUCTOR DEVICE**

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(21) Appl. No.: **18/533,721**

(22) Filed: **Dec. 8, 2023**

Related U.S. Application Data

(63) Continuation of application No. PCT/JP2022/024140, filed on Jun. 16, 2022.

(30) **Foreign Application Priority Data**

Jul. 6, 2021 (JP) 2021-112383

Publication Classification

(51) **Int. Cl.**
H01L 23/495 (2006.01)
H01L 23/31 (2006.01)

(52) **U.S. Cl.**
CPC ***H01L 23/49568*** (2013.01); ***H01L 23/3135*** (2013.01); ***H01L 23/4952*** (2013.01); ***H01L 23/49562*** (2013.01); ***H01L 23/49575*** (2013.01)

(57) **ABSTRACT**

A semiconductor device is configured to increase energy absorbed by an active clamp. The semiconductor device comprises a semiconductor element, a sealing resin, and a coating member. The semiconductor element includes a first electrode. The sealing resin covers the semiconductor element. The coating member is interposed between the first electrode and the sealing resin. The coating member contains a material with higher thermal conductivity than the sealing resin.

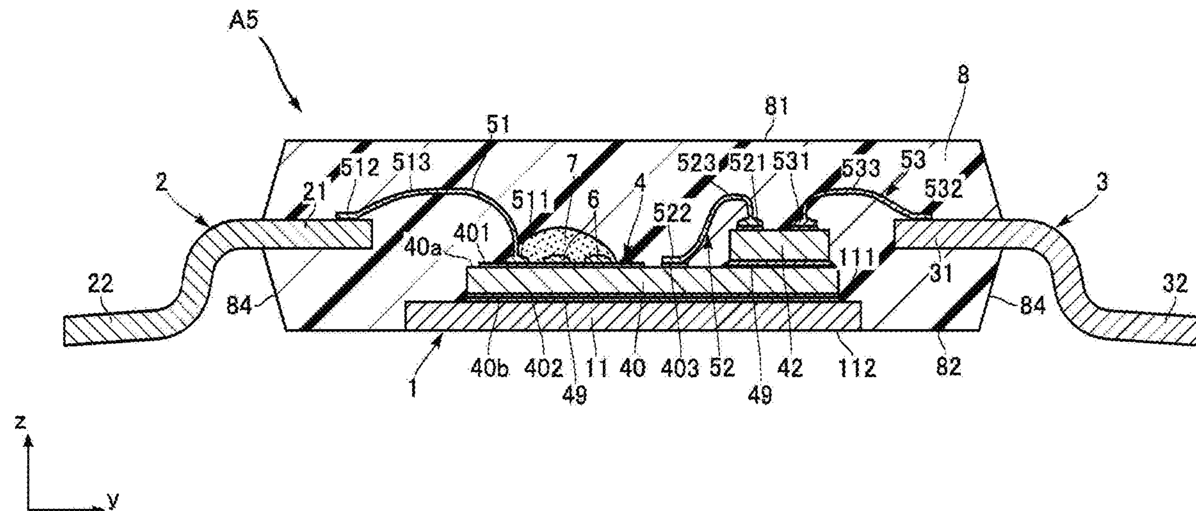


FIG.1

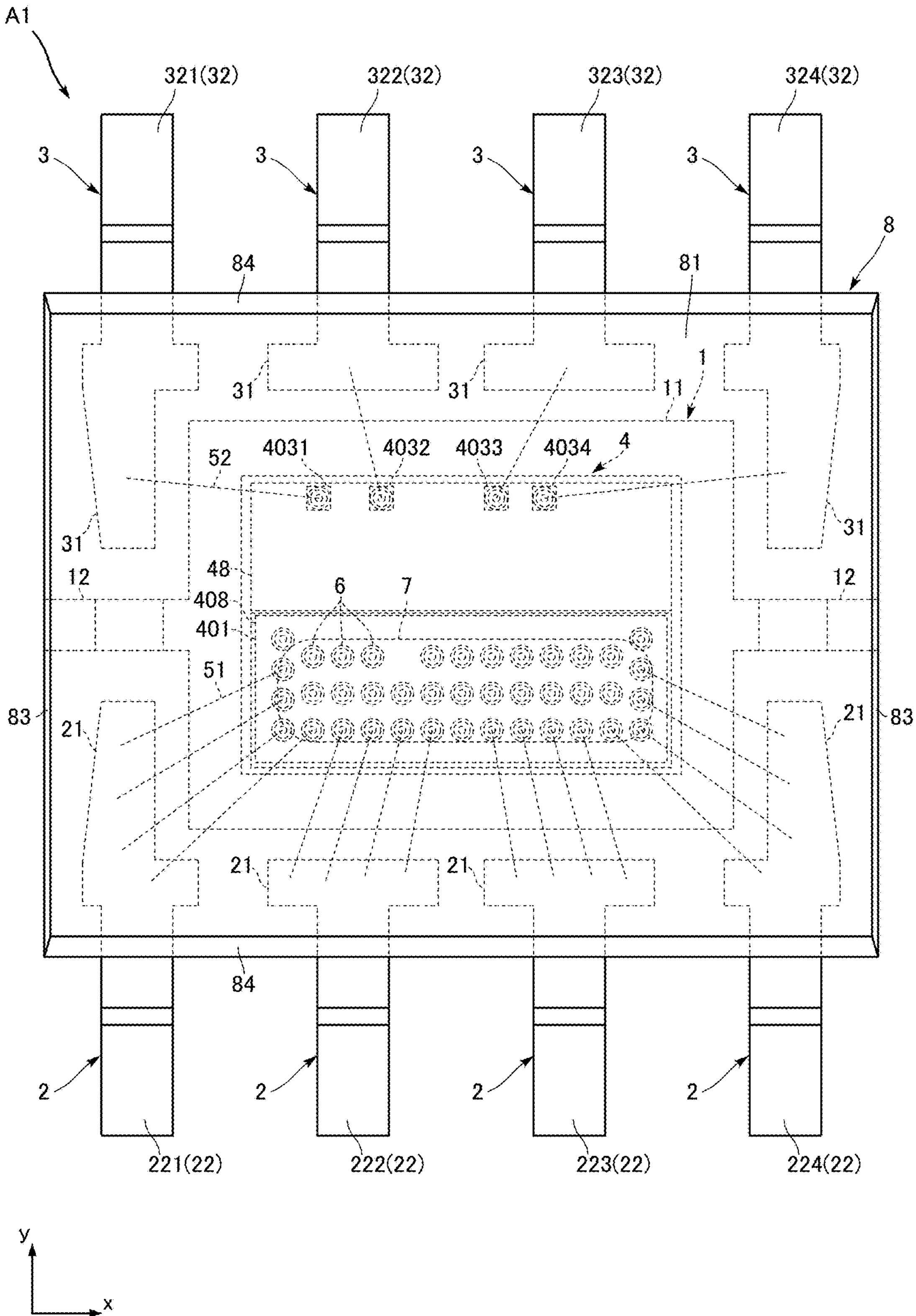


FIG.2

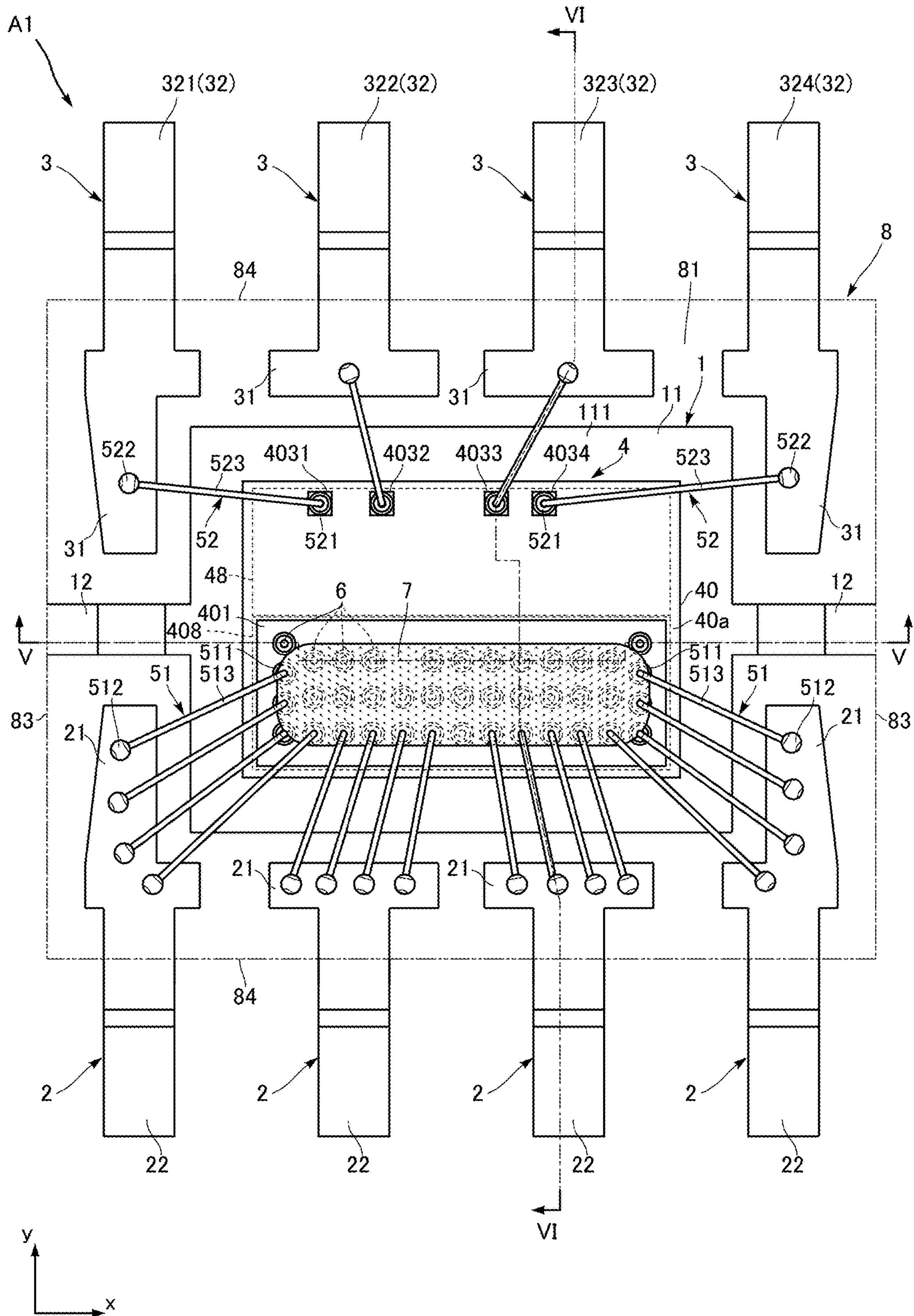


FIG.3

FIG.4

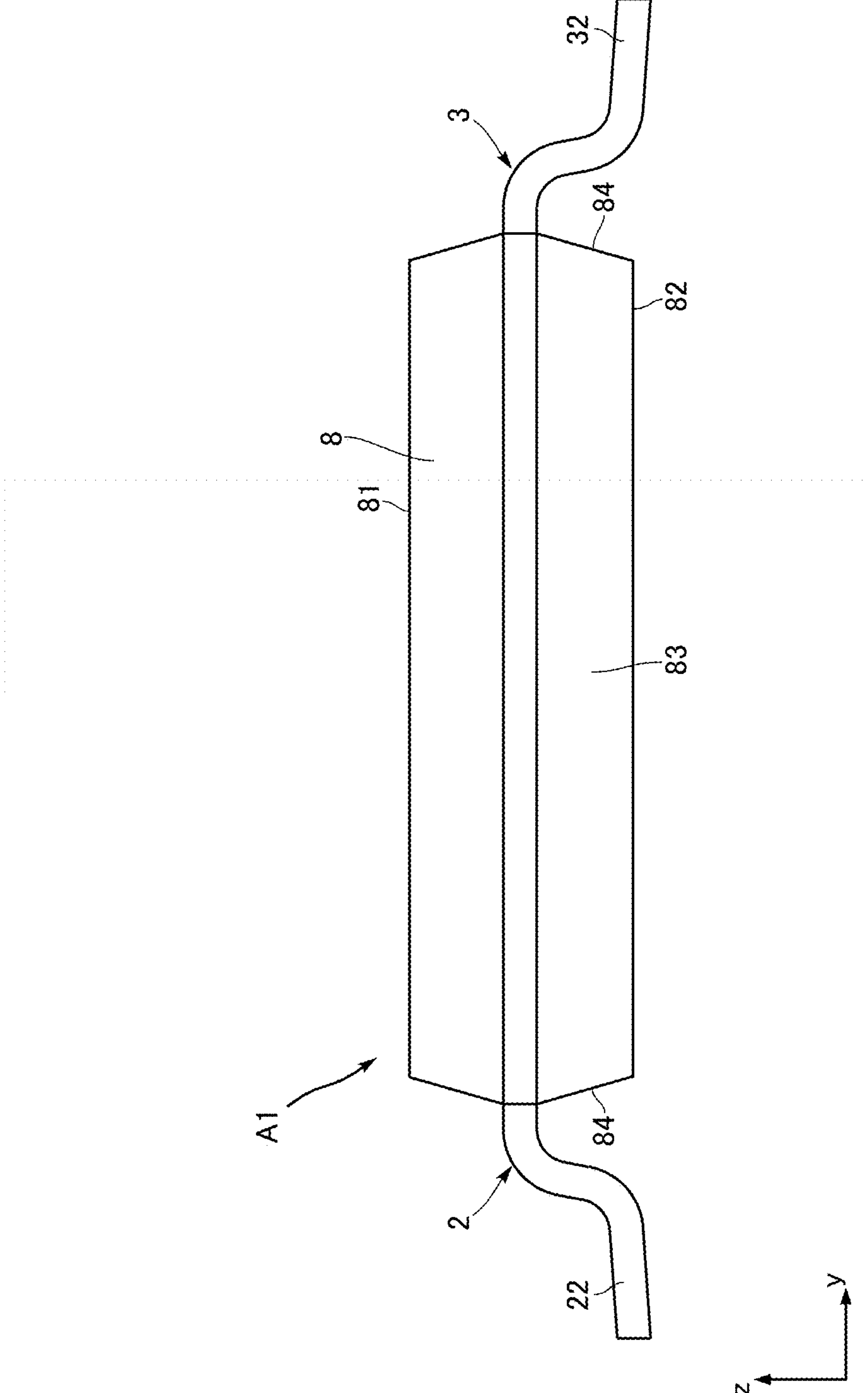
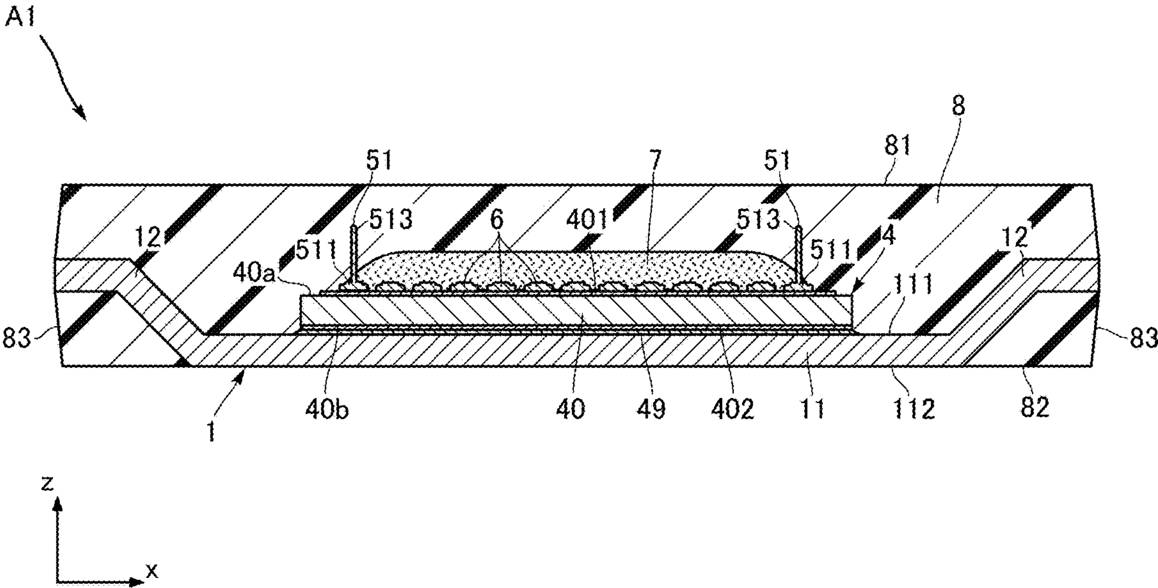


FIG.5

FIG.6



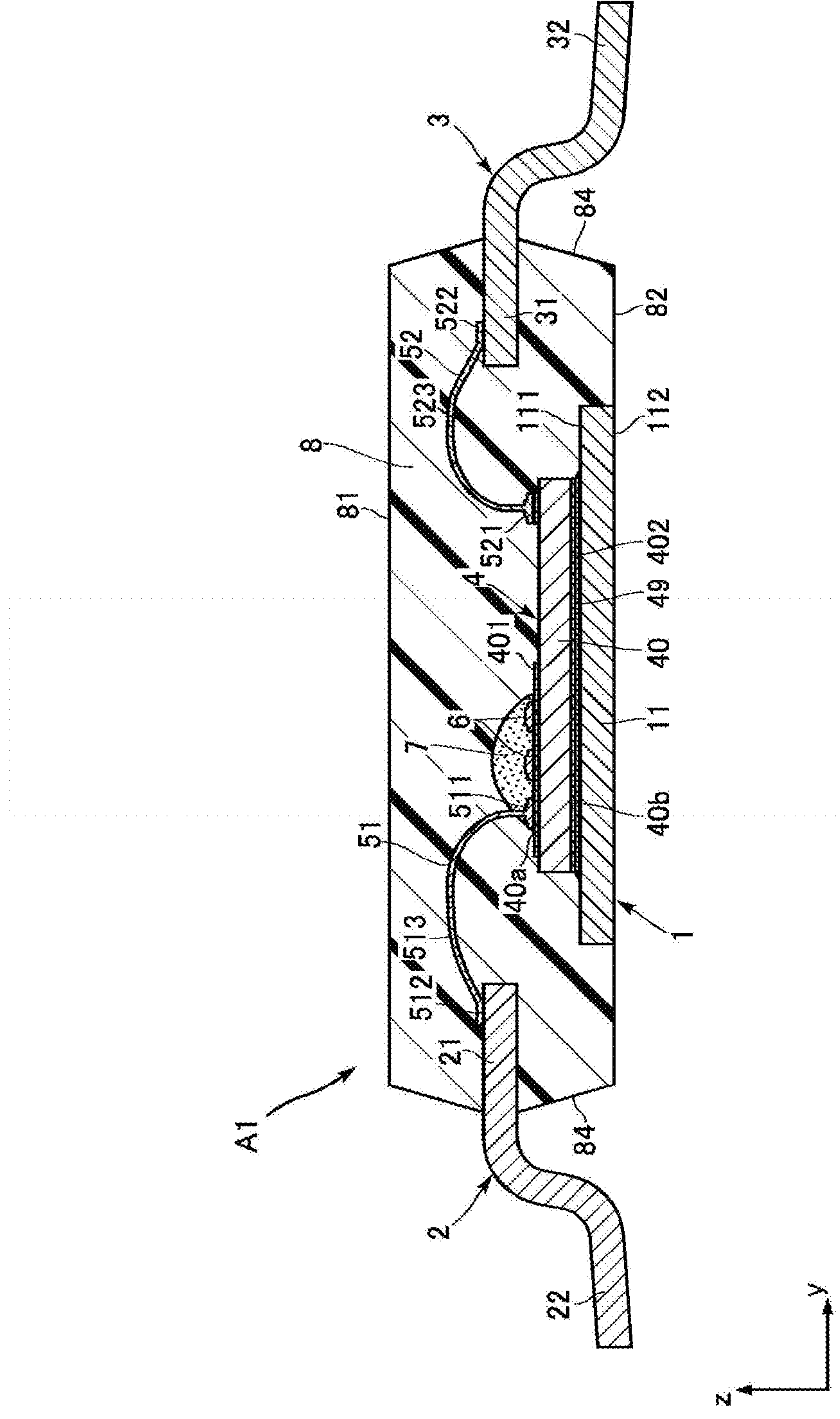


FIG.7

FIG.8

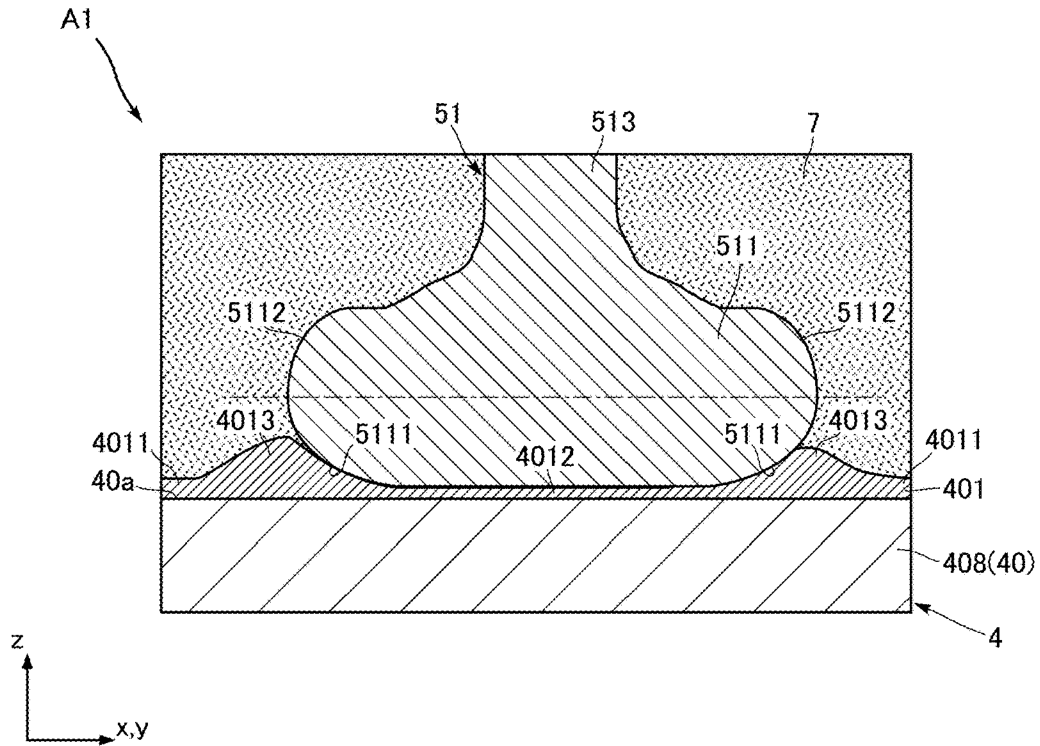


FIG.9

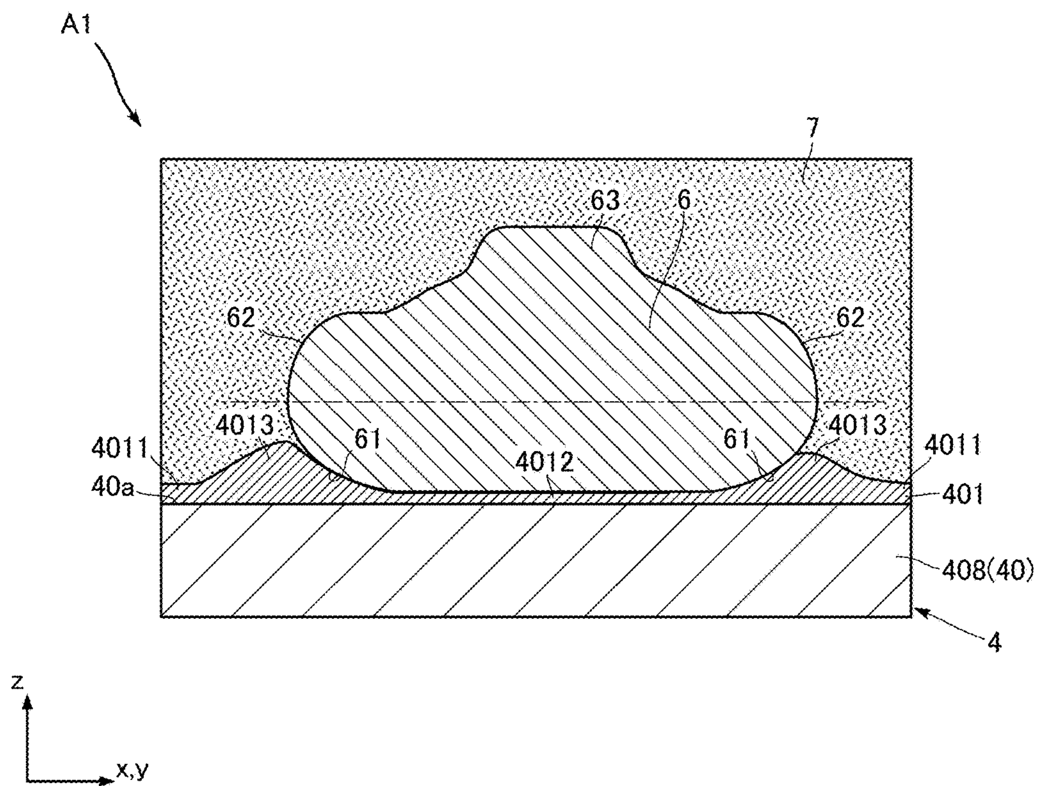


FIG.10

FIG.11

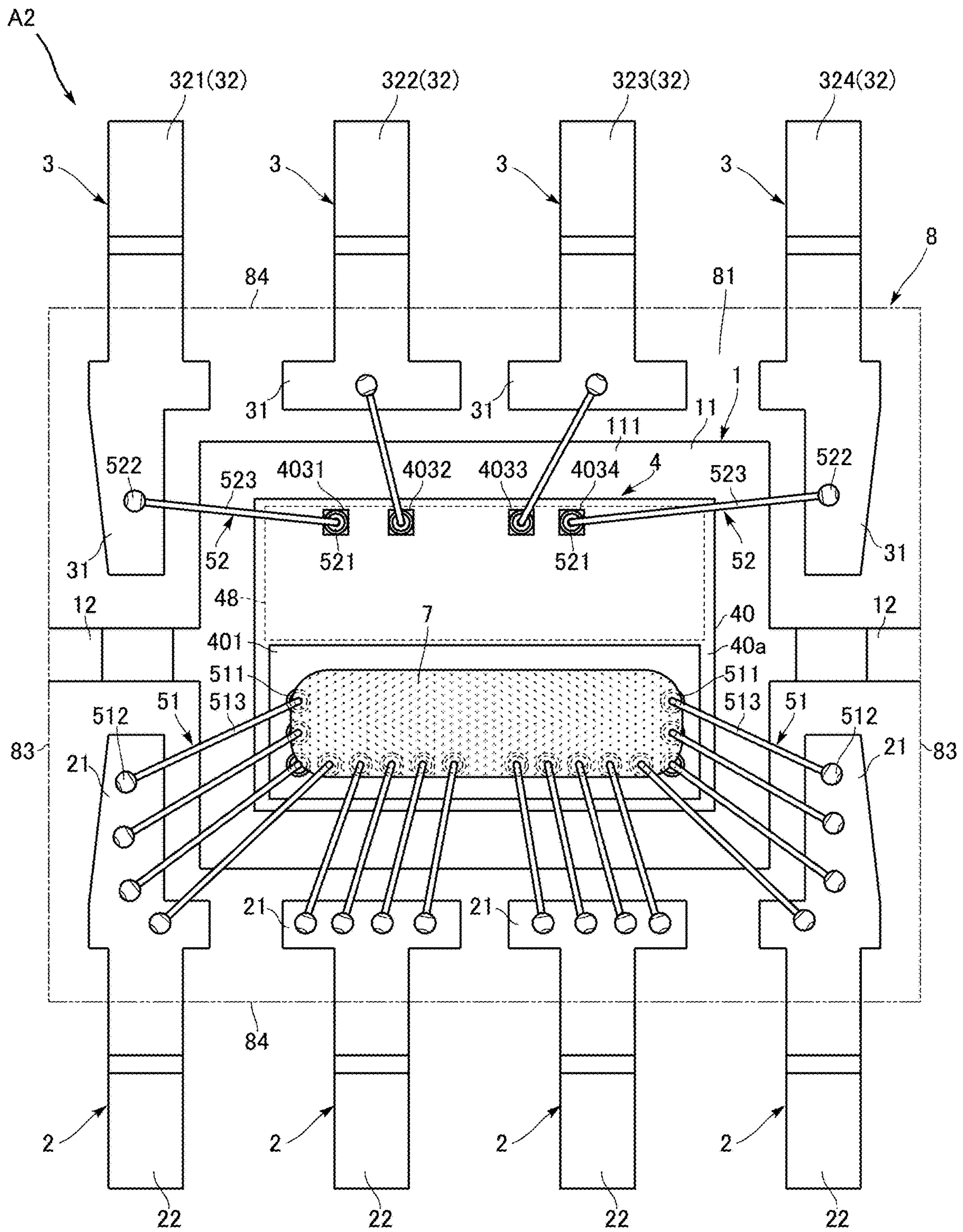


FIG.12

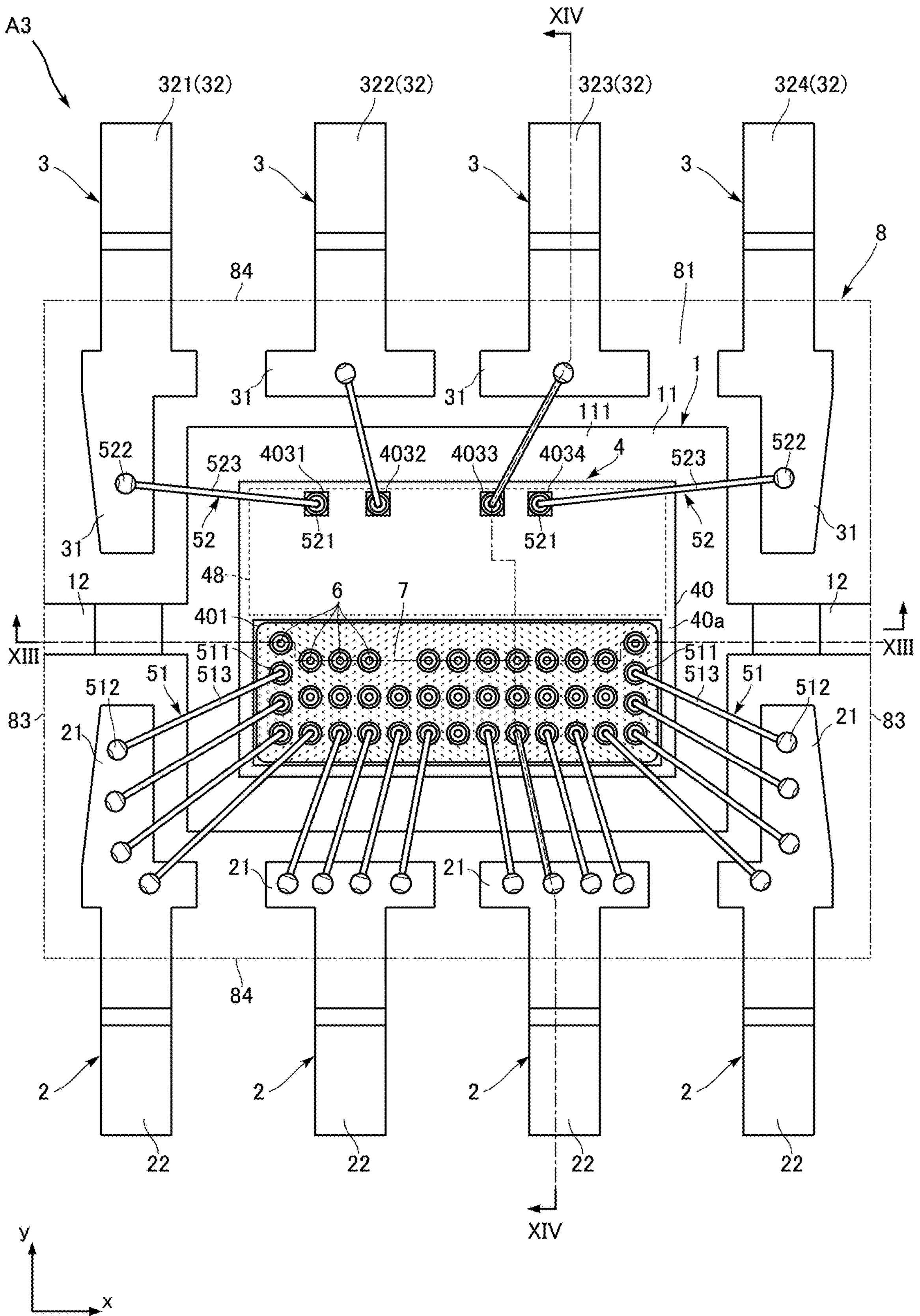


FIG.13

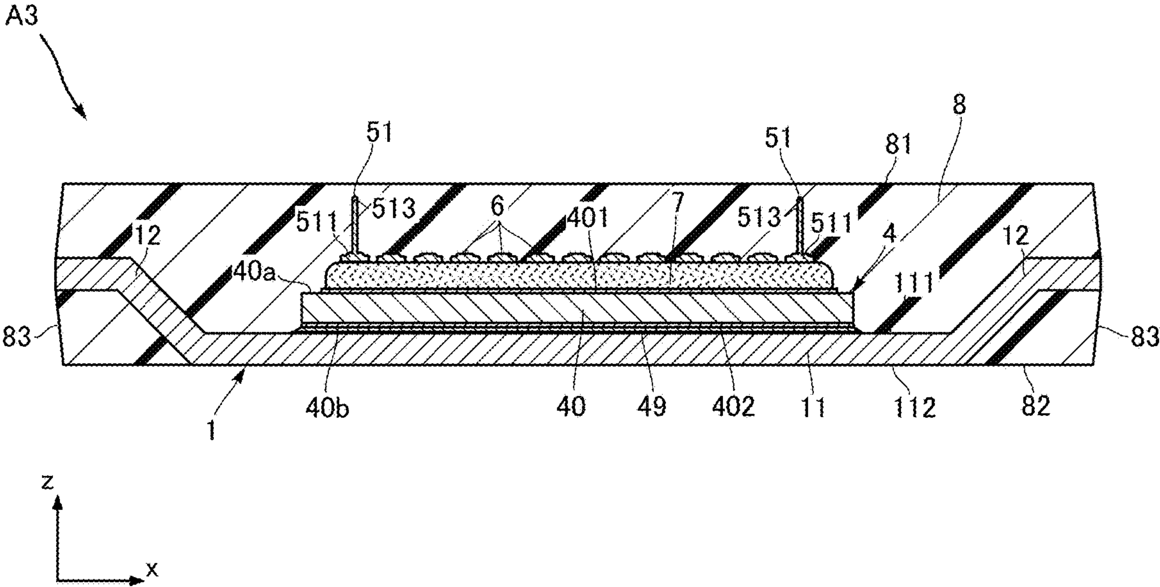


FIG.14

FIG.15

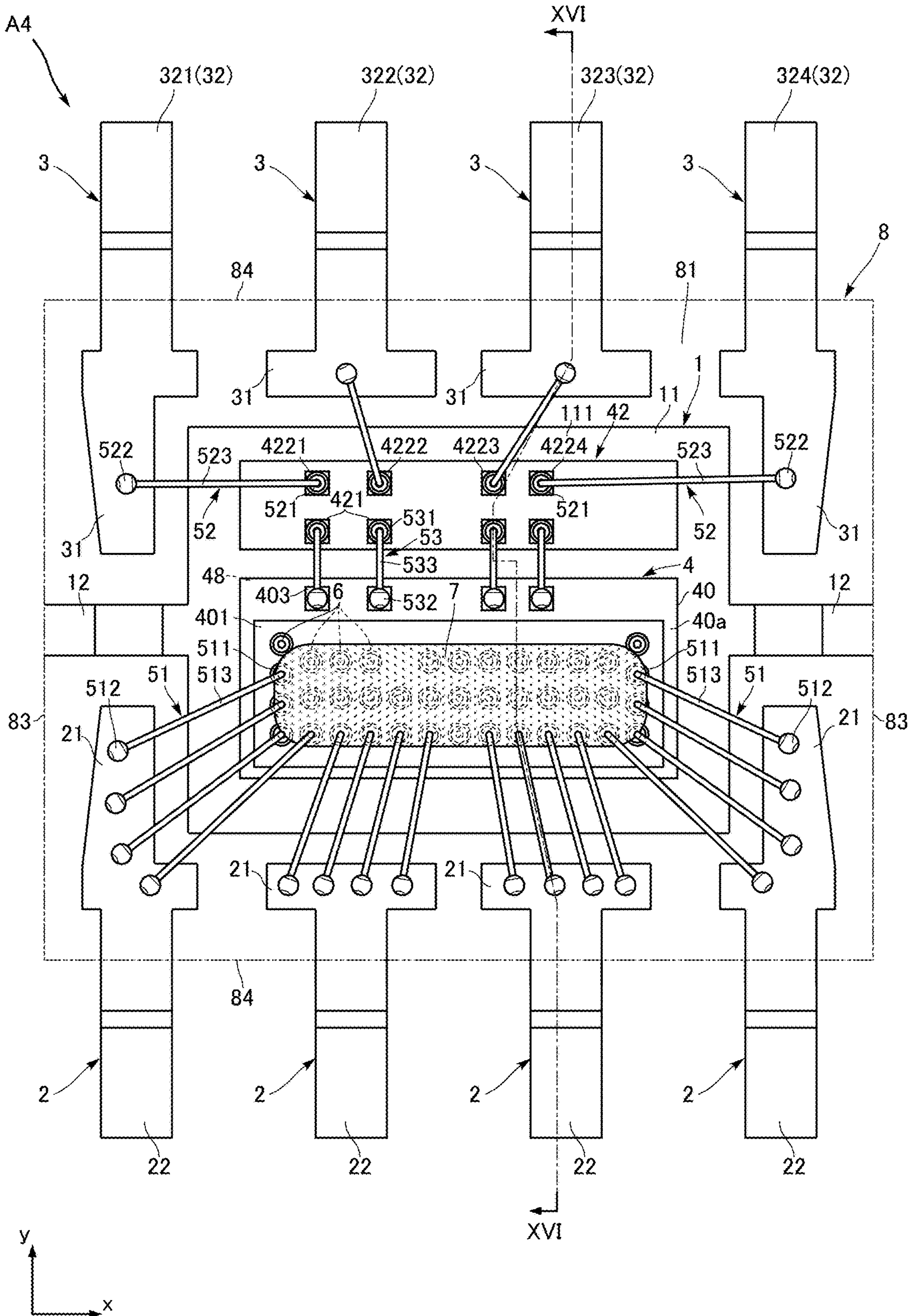


FIG.16

FIG.17

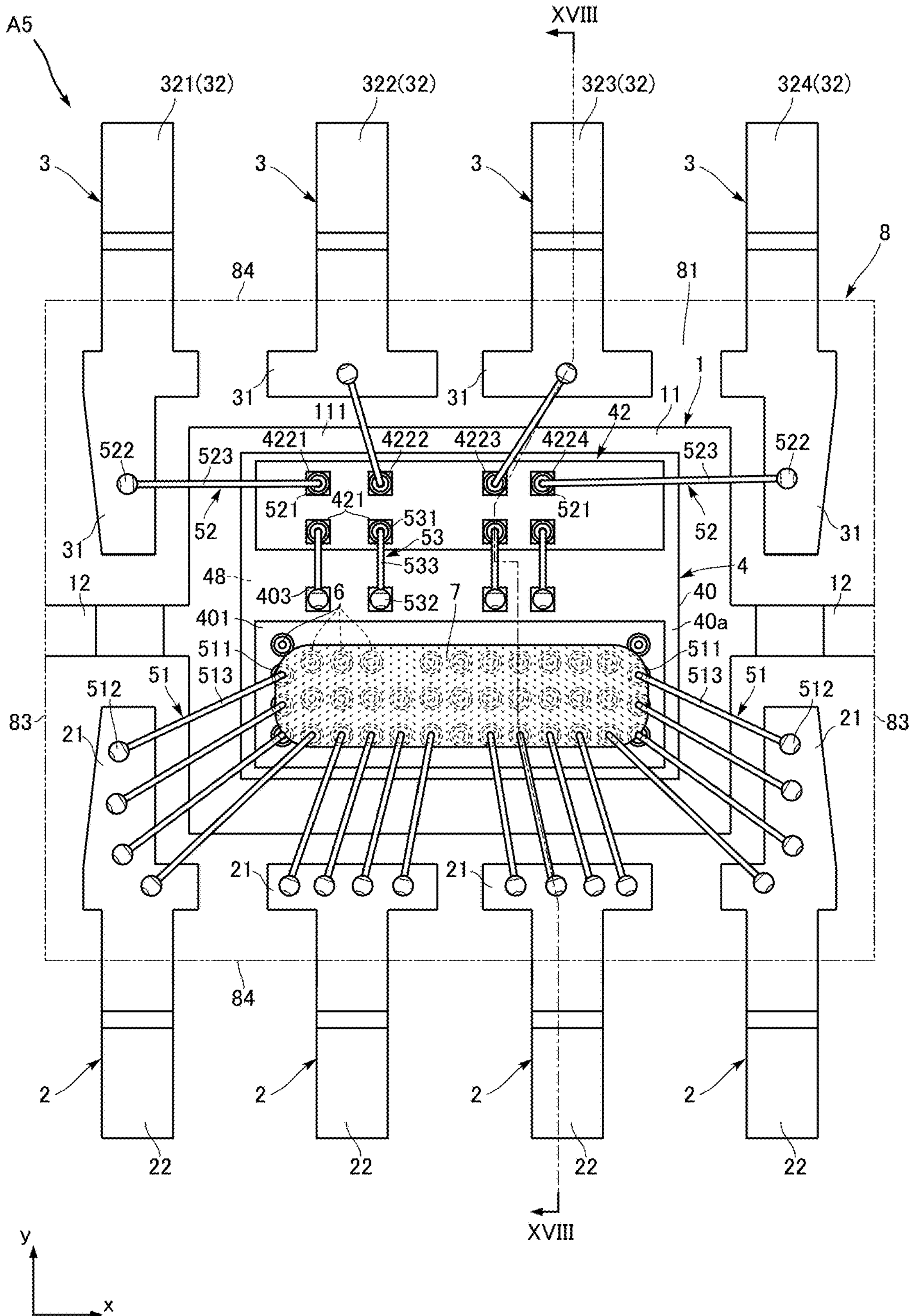
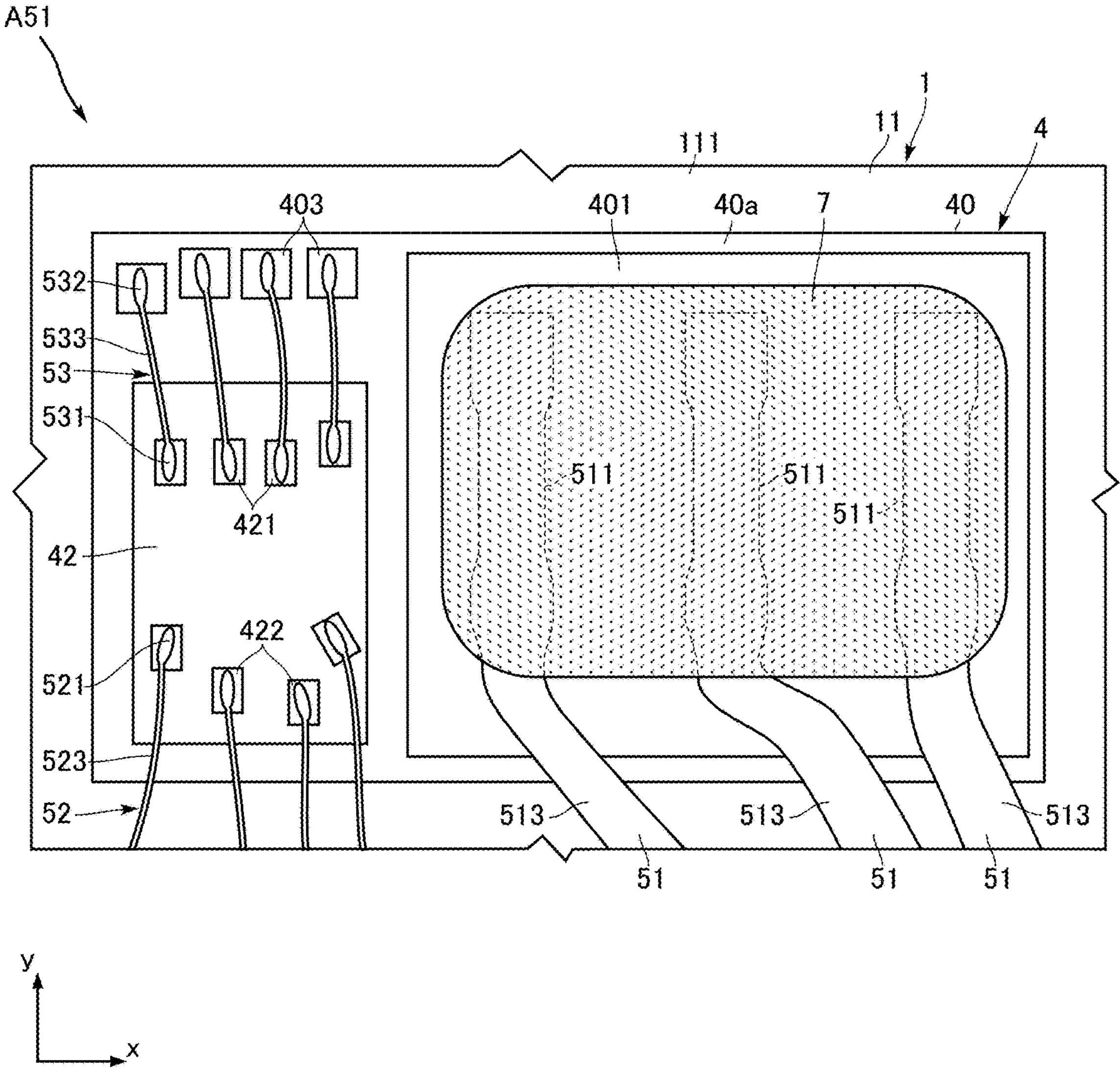


FIG.18

FIG.19



SEMICONDUCTOR DEVICE

TECHNICAL FIELD

[0001] The present disclosure relates to a semiconductor device.

BACKGROUND ART

[0002] Switching elements are used to control the flow of current in various industrial equipment and automobiles. An example of a conventional switching element is disclosed in JP-A-2019-212930. In the switching element, the electromotive force due to the current interruption generates energy. The active clamp functions to cause such energy to be absorbed by the switching element.

BRIEF DESCRIPTION OF THE DRAWINGS

[0003] FIG. **1** is a plan view of a semiconductor device according to a first embodiment of the present disclosure.

[0004] FIG. **2** is a plan view showing relevant parts of the semiconductor device according to the first embodiment of the present disclosure.

[0005] FIG. **3** is a circuit diagram of a semiconductor element in the semiconductor device according to the first embodiment of the present disclosure.

[0006] FIG. **4** is a front view of the semiconductor device according to the first embodiment of the present disclosure.

[0007] FIG. **5** is a side view of the semiconductor device according to the first embodiment of the present disclosure.

[0008] FIG. **6** is a cross-sectional view taken along lines V-V in FIG. **2**.

[0009] FIG. **7** is a cross-sectional view taken along lines VI-VI in FIG. **2**.

[0010] FIG. **8** is a partially enlarged cross-sectional view showing relevant parts of the semiconductor device according to the first embodiment of the present disclosure.

[0011] FIG. **9** is a partially enlarged cross-sectional view showing the relevant parts of the semiconductor device according to the first embodiment of the present disclosure.

[0012] FIG. **10** is a plan view showing a first variation of the semiconductor device according to the first embodiment of the present disclosure.

[0013] FIG. **11** is a plan view showing relevant parts of a semiconductor device according to a second embodiment of the present disclosure.

[0014] FIG. **12** is a plan view showing relevant parts of a semiconductor device according to a third embodiment of the present disclosure.

[0015] FIG. **13** is a cross-sectional view taken along lines XIII-XIII in FIG. **12**.

[0016] FIG. **14** a cross-sectional view taken along lines XIV-XIV in FIG. **12**.

[0017] FIG. **15** is a plan view showing relevant parts of a semiconductor device according to a fourth embodiment of the present disclosure.

[0018] FIG. **16** is a cross-sectional view taken along lines XVI-XVI in FIG. **15**.

[0019] FIG. **17** is a plan view showing relevant parts of a semiconductor device according to a fifth embodiment of the present disclosure.

[0020] FIG. **18** is a cross-sectional view taken along lines XVIII-XVIII in FIG. **17**.

[0021] FIG. **19** is a plan view showing relevant parts of a first variation of the semiconductor device according to the fifth embodiment of the present disclosure.

DETAILED DESCRIPTION OF EMBODIMENTS

[0022] The following describes preferred embodiments of semiconductor devices of the present disclosure with reference to the drawings.

[0023] In the present disclosure, the terms "first," "second," "third," etc. are used merely for the purpose of identification, and are not necessarily intended to order their objects.

[0024] FIGS. **1** to **9** show a semiconductor device A**1** according to a first embodiment of the present disclosure. The semiconductor device A**1** includes a first lead **1**, a plurality of second leads **2**, a plurality of third leads **3**, a semiconductor element **4**, a plurality of first wires **51**, a plurality of second wires **52**, a plurality of metal lumps **6**, a coating member **7**, and a sealing resin **8**. The shape and size of the semiconductor device A**1** are not limited. In one example of the semiconductor device A**1**, the size in the x direction is about within 4 to 7 mm, the size in the y direction is about within 4 to 8 mm, and the size in the z direction is about within 0.7 to 2.0 mm.

[0025] FIG. **1** is a plan view of the semiconductor device A**1**. FIG. **2** is a plan view showing relevant parts of the semiconductor device A**1**. FIG. **4** is a front view of the semiconductor device A**1**. FIG. **5** is a side view of the semiconductor device A**1**. FIG. **6** is a cross-sectional view taken along lines V-V in FIG. **2**. FIG. **7** is a cross-sectional view taken along lines VI-VI in FIG. **2**. FIG. **8** is a partially enlarged cross-sectional view showing relevant parts of the semiconductor device A**1**. FIG. **9** is a partially enlarged cross-sectional view showing relevant parts of the semiconductor device A**1**.

[0026] The first lead **1** supports the semiconductor element **4** and functions as an electrical conduction path to the semiconductor element **4**. The material of the first lead **1** is not limited, and it may include a metal such as Cu, Ni, Fe, or may include an alloy containing these metals. The first lead **1** may be formed with a plating layer made of a metal such as Ag, Ni, Pd, Au etc., in an appropriate location. The thickness of the first lead **1** is not limited, and may be about within 0.12 to 0.2 mm, for example.

[0027] The first lead **1** of the present embodiment includes a die pad section **11** and two extending sections **12**.

[0028] The die pad section **11** is a part supporting the semiconductor element **4**. The shape of the die pad section **11** is not limited, and may be a rectangle as viewed in the z direction. The die pad section **11** has a die pad obverse face **111** and a die pad reverse face **112**. The die pad obverse face **111** faces in the z direction. The die pad reverse face **112** faces opposite from the die pad obverse face **111** in the thickness direction. In the illustrated example, the die pad obverse face **111** and the die pad reverse face **112** are flat.

[0029] The two extending sections **12** are parts extending from the die pad section **11** to both sides of the x direction, respectively. In the present embodiment, each extending section **12** is bent as a whole, including a first part extending from the die pad portion **11** along the x direction, a second part inclined relative to the first part toward the side of the z direction in which the die pad obverse face **111** faces, and a third part extending from the second part along the x direction.

[0030] The second leads **2** are spaced apart from the first lead **1** and function as electrical conduction paths to the semiconductor element **4**. In the present embodiment, the second leads **2** provide electrical conduction paths, through which an electrical current to be switched by the semiconductor element **4** flows. The second leads **2** are disposed in one side of the y direction with respect to the first lead **1**. The second leads **2** are spaced apart from each other in the x direction.

[0031] The material of the second leads **2** is not limited, and it may include a metal, such as Cu, Ni, Fe, or may include an alloy containing these metals. Each second lead **2** may be formed with a plating layer made of a metal, such as Ag, Ni, Pd, Au etc., in an appropriate location. The thickness of each second lead **2** is not limited, and may be about within 0.12 to 0.2 mm, for example.

[0032] Each second lead **2** of the present embodiment includes a pad section **21** and a terminal section **22**.

[0033] The pad section **21** is a part to which a relevant first wire(s) **51** is connected. In the present embodiment, in the z direction, the pad section **21** is located away from the die pad section **11** in the direction in which the die pad obverse face **111** faces.

[0034] The terminal section **22** is a strip-like part extending outwardly from the pad section **21** in the y direction. The terminal section **22** is bent as viewed in the x direction, with its front edge disposed generally at the same location as the die pad section **11** in the z direction. In the illustrated example, the terminal section **22** is a power supply terminal.

[0035] The third leads **3** are spaced apart from the first lead **1** and function as electrical conduction paths to the semiconductor element **4**. In the present embodiment, the third leads **3** provide electrical conduction paths for a control signal current to control the semiconductor element **4**. The third leads **3** are disposed on the other side of the first lead **1** in the y direction. The third leads **3** are spaced apart from each other in the x direction.

[0036] The material of the third leads **3** is not limited, and it may include a metal, such as Cu, Ni, Fe, or may include an alloy containing these metals. Each third lead **3** may be formed with a plating layer made of a metal, such as Ag, Ni, Pd, Au etc., in an appropriate location. The thickness of each third lead **3** is not limited, and may be about in a range of 0.12 to 0.2 mm, for example.

[0037] Each third lead **3** of the present embodiment includes a pad section **31** and a terminal section **32**.

[0038] The pad section **31** is a part to which a relevant second wire(s) **52** is connected. In the present embodiment, in the z direction, the pad section **31** is located away from the die pad section **11** in the direction in which the die pad obverse face **111** faces.

[0039] The terminal section **32** is a strip-like part extending outwardly from the pad section **31** in the y direction. The terminal section **32** is bent as viewed in the x direction, with its front edge disposed at the same (or generally at the same) location as the die pad section **11** in the z direction.

[0040] As shown in FIG. **2**, the terminal sections **32** of the third leads **3** are labeled as terminal sections **321**, **322**, **323**, **324**. The terminal section **321** is an output terminal electrically connected to the third electrode **4031** described later. The terminal section **322** is a ground terminal electrically connected to the third electrode **4032** described later. The terminal section **323** is a self-monitoring output terminal electrically connected to the third electrode **4033** described later. The terminal section **324** is an input terminal electrically connected to the third electrode **4034** described later.

[0041] In the semiconductor device A**1**, the semiconductor element **4** provides an electrical function. In the present embodiment, the semiconductor element **4** performs switching. The semiconductor element **4** includes an element body **40**, a first electrode **401**, a second electrode **402**, and a plurality of third electrodes **403**. The semiconductor element **4** includes a switching section **408** in which transistors are formed to perform switching, and a control section **48** for e.g., controlling, monitoring and protecting the transistors of the switching section **408**. The control section **48** may include transistors of a horizontal structure type.

[0042] The element body **40** has an element obverse face **40***a* and an element reverse face **40***b*. In the z direction, the element obverse face **40***a* faces the same direction as the die pad obverse face **111**. In the z direction, the element reverse face **40***b* faces opposite from the element obverse face **40***a*. The material of the element body **40** is not limited. For example, the element body **40** may be made of a semiconductor material, such as Si, SiC, GaN.

[0043] The element body **40** has the switching section **408**. The switching section **408** is provided with a transistor structure, such as a MOSFET (Metal Oxide Semiconductor Field Effect Transistor) or a MISFET (Metal Insulator Semiconductor Field Effect Transistor). As shown in FIGS. **1** and **2**, as viewed in the z direction, the switching section **408** and the control section **48** are arranged side by side in the y direction. However, the specific arrangement of the switching section **408** and the control section **48** is not limited.

[0044] The first electrode **401** is disposed on the element obverse face **40***a*. In the illustrated example, in the y direction, the first electrode **401** is disposed at the same location as the second leads **2** in the element obverse face **40***a*. As viewed in the z direction, the first electrode **401** overlaps with the switching section **408**. In the present embodiment, as viewed in the z direction, the first electrode **401** is spaced apart from the control section **48**. In the present embodiment, the first electrode **401** is a source electrode. The material of the first electrode **401** is not limited, and it may include a metal, such as Al (aluminum), Al-Si, Cu (cupper), or may include an alloy containing these metals. The first electrode **401** may have a lamination consisting of layers of different materials selected from these metals.

[0045] As shown in FIGS. **8** and **9**, the first electrode **401** includes a base thickness section **4011**, a reduced thickness section **4012**, and a bulging section **4013**. The base thickness section **4011** corresponds to most of the area of the first electrode **401** where the bonding sections **511** of the first wires **51** and the metal lumps **6** described later are not provided. The thickness of the base thickness section **4011**, for example, corresponds to the thickness after a treatment, such as plating for forming the first electrode **401**, is completed.

[0046] The reduced thickness section **4012** is a part of the first electrode **401** where either the bonding section **511** or the metal lump **6** is joined, and is thinner than the base thickness section **4011**. The reduced thickness section **4012** is, for example, a thinned section resulting from the joining process of the bonding section **511** or the metal lump **6**.

[0047] The bulging section **4013** is a part between the base thickness section **4011** and the reduced thickness section **4012**. The bulging section **4013** surrounds the reduced

thickness section **4012**. The bulging section **4013** is thicker than the base thickness section **4011** and the reduced thickness section **4012**.

[0048] The second electrode **402** is disposed on the element reverse face **40***b* of the element body **40**. As viewed in the z direction, the second electrode **402** overlaps with the switching section **408** and the control section **48**, and in the present embodiment, the second electrode **402** covers the entirety of the element reverse face **40***b*. In the present embodiment, the second electrode **402** is a drain electrode. The material of the second electrode **402** is not limited, and it may include a metal, such as Al (aluminum), Al-Si, Cu (cupper), or may include an alloy containing these metals. The second electrode **402** may have a lamination consisting of layers of different materials selected from these metals.

[0049] The specific configuration of the control section **48** is not limited. The control section **48** may include a current sensor circuit, a temperature sensor circuit, an overcurrent protection circuit, a thermal protection circuit, and a low-voltage malfunction prevention circuit.

[0050] The third electrodes **403** are disposed on the element obverse face **40***a*. In the illustrated example, in the y direction, the third electrodes **403** are disposed at the same location as the third leads **3** in the element obverse face **40***a*. As viewed in the z direction, the third electrodes **403** overlap with the control section **48**. In the present embodiment, the third electrodes **403** mainly conduct to the control section **48**. The number of the third electrodes **403** is not limited. The number of the third electrode **403** may be one. In the illustrated example, the semiconductor element **4** has four third electrodes **403**.

[0051] In the illustrated example, the four third electrodes **403** include third electrodes **4031**, **4032**, **4033**, **4034**. The third electrode **4031** is an output electrode, whose output current is limited when the load is in a short state and current exceeds the overcurrent detection value. The third electrode **4032** is a ground electrode. The third electrode **4033** is a self-monitoring output electrode, whose potential varies depending on whether or not an overcurrent state or overheated state (or both) is detected. The third electrode **4034** is an input electrode, to which a pull-down resistor is connected internally.

[0052] FIG. **3** shows an example of the circuit in the switching section **408** and the control section **48**. The switching section includes transistors. The control section **48** includes an energy absorption circuit **481** and a protection circuit **482**. The energy absorption circuit **481** is a circuit configured to absorb electrical energy caused by e.g., transient voltage, including a Zener diode and a resistor. The protection circuit **482** is a circuit configured to protect the control section **48**, including a heat protection section **4821** and an overcurrent protection section **4822**.

[0053] The first wires **51** electrically connect the first electrode **401** of the semiconductor element **4** with the second leads **2**. The material of the first wires **51** is not limited, and it may include a metal, such as Au, Cu, or Al. The metals included in the first wires **51** may be different from the metals included in the first electrode **401**. Each first wire **51** includes a bonding section **511**, a bonding section **512** and a loop section **513**. The specific configuration of each first wire **51** is not limited. In the illustrated example, the first wires **51** are made of a material including Cu and are provided by a capillary, for example. In the present embodiment, an electrical current to be switched by the semiconductor element **4** flows through the first wires **51**.

[0054] The semiconductor device according to the present disclosure is not limited to the configuration that the first wires **51** are joined to the first electrode **401**. For example, a conductive member provided by a metal plate rather than the first wires **51** may be connected to the first electrode **401**. Alternatively, use may be made of another electrode conducting to the first electrode **401** via a conductive path provided within the semiconductor element **4**, and the conductive members such as the first wires **51** may be in contact with the electrode.

[0055] Each bonding section **511** conducts to the first electrode **401** of the semiconductor element **4**, and is located at the position overlapping with the first electrode **401** as viewed in the z direction. In the present embodiment, each bonding section **511** is joined to the first electrode **401**, corresponding to a so-called first bonding section.

[0056] As shown in FIG. **8**, each bonding section **511** has a first face **5111** and a second face **5112**. The first face **5111** and the second face **5112** are arranged along the z direction with the intervention of the maximum diameter portion of the bonding section **511** (the portion of the maximum dimension in a direction perpendicular to the z direction, such as the x direction and the y direction; see the portion intersecting the dashed line shown in FIG. **8**).

[0057] The first face **5111** is inclined such that it is located further away from the center of the bonding section **511** in any direction perpendicular to the z direction, such as the x direction or the y direction, as it proceeds further away from the first electrode **401** in the z direction. In the illustrated example, the first face **5111** is a convex curved surface. The second face **5112** is located opposite to the first face **5111** with the maximum diameter portion sandwiched. In the illustrated example, the second face **5112** is a convex curved surface.

[0058] The bonding section **512** is a part joined to the pad section **21** of the relative second lead **2**. The bonding section **512** corresponds to a so-called second bonding section.

[0059] The loop section **513** is connected to the bonding section **511** and the bonding section **512**, and is, for example, bent as a whole.

[0060] In the illustrated example, the bonding sections **511** are arranged along the outer edge of the first electrode **401**. More specifically, the bonding sections **511** are arranged along the three sides included in the outer edge of the element body **40**. The bonding sections **511** are arranged in a single row extending along the outer edge of the first electrode **401**.

[0061] The second wires **52** electrically connect the third electrodes **403** of the semiconductor element **4** with the third leads **3**. The material of the second wires **52** is not limited, and it may include a metal, such as Au, Cu, or Al. Each second wire **52** includes a bonding section **521**, a bonding section **522** and a loop section **523**. The specific configuration of each second wire **52** is not limited. In the illustrated example, the second wires **52** are provided by a capillary, for example. In the present embodiment, an electrical current to control the semiconductor element **4** flows through the second wires **52**. In the example shown in FIG. **2**, one of the second wires **52** connects the third electrode **4031** with the pad section **31** of the third lead **3** having the terminal section **321**. One of the second wires **52** connects the third electrode **4032** with the pad section **31** of the third lead **3** having the

terminal section **322**. One of the second wires **52** connects the third electrode **4033** with the pad section **31** of the third lead **3** having the terminal section **323**. One of the second wires **52** connects the third electrode **4034** with the pad section **31** of the third lead **3** having the terminal section **324**.

[0062] The bonding section **521** is bonded to the third electrode **403** of the semiconductor element **4**. The bonding section **521** corresponds to a so-called first bonding section.

[0063] The bonding section **522** is bonded to the pad section **31** of the third lead **3**. The bonding section **522** corresponds to a so-called second bonding section.

[0064] The loop section **523** is connected to the bonding section **521** and the bonding section **522**, and is, for example, bent as a whole.

[0065] Each of the metal lumps **6** includes a metal and is bonded to the first electrode **401**. The specific configuration of each metal lump **6** is not limited. In the present embodiment, each metal lump **6** has the same configuration as the bonding section **511** of the first wire **51**. Specifically, the metal lumps **6** are provided by cutting the wire material after the bonding section **511** is formed in the formation process of the first wire **51** using a capillary. Each metal lump **6** according to the present embodiment includes Cu. The number of the metal lumps **6** is not limited, and may be one. The semiconductor device according to the present disclosure may be configured without the metal lumps **6**.

[0066] The arrangement of the metal lumps **6** is not limited. In the illustrated example, the metal lumps **6** are arranged inward of the first electrode **401**. In other words, the metal lumps **6** are opposite to the outer edge of the first electrode **401** with respect to the bonding sections **511**. In addition, the metal lumps **6** are arranged in a matrix. Possible arrangements of the metal lumps **6** in a matrix include an arrangement of multiple intersecting rows along x and y directions, or a so-called staggered arrangement.

[0067] As shown in FIG. **9**, the metal lump **6** includes a first face **61**, a second face **62**, and a projection **63**. The first face **61** and the second face **62** are arranged vertically with a maximum diameter portion of the metal lump **6** (the portion having the maximum dimension in a direction perpendicular to the z direction, such as the x direction or the y direction; see the portion intersecting the dashed line shown in FIG. **9**) sandwiched between them in the z direction.

[0068] The first face **61** is inclined such that it is located further away from the center of the metal lump **6** in any direction perpendicular to the z direction, such as the x direction or the y direction, as it proceeds further away from the first electrode **401** in the z direction. In the illustrated example, the first face **61** is a convex curved surface. The second face **62** is located opposite to the first face **61** with the maximum diameter portion sandwiched. In the illustrated example, the second face **62** is a convex curved surface.

[0069] The projection **63** is a part protruding from the second face **62** to the opposite side of the first electrode **401** in the z direction. In the present example, the projection **63** results from cutting the wire material to provide the metal lump **6**.

[0070] The coating member **7** is interposed between the first electrode **401** and the sealing resin **8**. The coating member **7** contains a material with higher thermal conductivity than the sealing resin **8**. The material of the coating member **7** is not limited, and it may include a metal in the case that the sealing resin **8** is made of an insulating resin. The coating member **7** may contain a metal different from the metal contained in the first electrode **401**. A metal for providing the coating member **7** may be e.g., Ag or Cu. In an embodiment, the coating member **7** may contain sintered Ag or sintered Cu. When sintered Ag is contained in the coating member **7**, preferably use may be made of a type of sintered Ag that can be formed without pressure. In the case the coating member **7** is made of sintered Ag formable without pressure, the coating member **7** may be formed by emitting from a nozzle the material paste, which will be the sintered Ag, and then heating the applied material paste in an appropriate manner.

[0071] The material of the coating member **7** is not limited to a metal. For instance, it may contain a resin with higher thermal conductivity than the insulating resin forming the sealing resin **8**. In the case that the sealing resin **8** is made of epoxy resin, the constituent resin of the coating member **7** may include e.g., PC (polycarbonate), PA6 (nylon 6), PPS (polyphenylene sulfide), PBT (polybutylene terephthalate). For the coating member **7**, these resins may be mixed with fillers to increase thermal conductivity.

[0072] In the present example, the coating member **7** contains sintered Ag, and is in contact with both of the first electrode **401** and the sealing resin **8**. As viewed in the z direction, the coating member **7** is disposed inward of the outer edge of the first electrode **401**.

[0073] In the present example, the coating member **7** is in contact with at least one of the metal lumps **6**. The coating member **7** is also in contact with at least one of the bonding sections **511** of the first wires **51**. In the illustrated example, the coating member **7** covers most of the metal lumps **6**. In the illustrated example, the coating member **7** also covers most of the bonding sections **511** of the first wires **51**. As shown in FIG. **2**, the coating member **7** is disposed at the area surrounded by the bonding sections **511** of the first wires **51**.

[0074] As shown in FIGS. **6** and **7**, the maximum thickness of the coating member **7** is greater than the bonding section **511** of the first wire **51**. As viewed in the z direction, the thickness of the coating member **7** is greater at the center than at the periphery. The maximum thickness of the coating member is preferably at least 20 μm, more preferably at least 80 μm, and even more preferably at least 160 μm. The thickness of the coating member **7** may vary depending on locations in a manner such that the coating member **7** has two portions of maximum value separated from each other in the y direction and has a portion of minimum value between the two portions.

[0075] As shown in FIG. **8**, in the illustrated example, the coating member **7** includes a portion wedged between the first electrode **401** (the bulging section **4013**) and the first face **5111** of the relevant bonding section **511**. In other word, the coating member **7** includes a portion that surrounds the bonding section **511** below its largest diameter part.

[0076] As shown in FIG. **9**, in the illustrated example, the coating member **7** includes a portion wedged between the first electrode **401** (the bulging section **4013**) and the first face **61** of the metal lump **6**. In other word, the coating member **7** includes a portion that surrounds the first face **61** below its largest diameter part.

[0077] The sealing resin **8** covers the first lead **1** and a part of each of the second leads **2** and the third leads **3**, while also covering the semiconductor element **4**, the first wires **51**, the

second wires **52**, the metal lumps **6**, and the coating member **7**. The sealing resin **8** may be made of an insulating resin, such as epoxy resin mixed with fillers.

[0078] The shape of the sealing resin **8** is not limited. In the illustrated example, the sealing resin **8** has a resin obverse face **81**, a resin reverse face **82**, two first resin side faces **83**, and two second resin side faces **84**.

[0079] The resin obverse face **81** faces the same side in the z direction as the die pad obverse face **111**, and may be flat.

[0080] The resin reverse face **82** faces opposite to the resin obverse face **81** in the z direction, and may be flat.

[0081] The two first resin side faces **83** are located between the resin obverse face **81** and the resin reverse face **82** in the z direction, and are arranged to face the opposite sides of the x direction, respectively. The two second resin side faces **84** are located between the resin obverse face **81** and the resin reverse face **82** in the z direction, and are arranged to face the opposite sides of the y direction, respectively.

[0082] Effects of the semiconductor device A**1** may be as follows.

[0083] When operating the semiconductor element **4**, at least a part of the energy generated by the electromotive force due to the current interruption converts into heat. The accumulation of the heat in the semiconductor element **4** may result in an excessively high temperature of the semiconductor element **4**. The semiconductor device A**1** includes the coating member **7** between the first electrode **401** and the sealing resin **8**. The coating member **7** contains a material with higher thermal conductivity than the sealing resin **8**. Hence, heat transfer from the first electrode **401** to the coating member **7** is promoted, so that an excessively high temperature in the semiconductor element **4** can be suppressed. Thus, the semiconductor device A**1** can increase the energy absorbed by an active clamp.

[0084] In the case that the coating member **7** contains a metal, the heat transfer from the first electrode **401** is further promoted. In the case that the coating member **7** contains a metal, in particular Ag or Cu, the heat transfer across the coating member **7** is further promoted. In the case that the coating member **7** contains sintered Ag or sintered Cu, the desired shape of the coating member **7** can be obtained more reliably by emitting the material paste and then sintering the applied material paste.

[0085] In the case that the coating member **7** contains a metal, the coating member **7** is provided as a conductive member in contact with the first electrode **401**. Thus, the conductive path from the switching section **408** to one of the first wires **51** can be provided by the coating member **7** in addition to the first electrode **401**. Thus, the resistance of the semiconductor element **4** can be reduced.

[0086] The coating member **7** is in contact with the bonding section **511** of the first wires **51**, so that a heat transfer path, which can mutually transfer heat between the coating member **7** and the first wires **51**, is provided. Thus, the heat transferred to the coating member **7** can be released to the second leads **2** via the first wires **51**.

[0087] In the case that the first electrode **401** contains Al and the coating member **7** contains sintered Ag, the bond between the first electrode **401** and the coating member **7** may not be strong enough. On the other hand, in the case that the first wires **51** contain Cu, the bond between the first electrode **401** and the first wires **51** and the bond between the first wires **51** and the coating member **7** are stronger than the bond between the first electrode **401** and the coating member **7**. Hence, the separation of the coating member **7** from the first electrode **401** can be suppressed.

[0088] As shown in FIG. **8**, in the present embodiment, the coating member **7** includes a portion wedged between the first electrode **401** (the bulging section **4013**) and the first face **5111** of the bonding section **511**. In other word, the coating member **7** includes a portion that surrounds the bonding section **511** below its largest diameter part. Thus, the separation of the coating member **7** can be further suppressed.

[0089] The semiconductor device A**1** includes the metal lumps **6**. The thermal conductivity of the metal lumps **6** is higher than the sealing resin **8**. Hence, the energy absorbed by an active clamp can be further increased.

[0090] In the case that the first electrode **401** contains Al and the coating member **7** contains sintered Ag, the bond between the first electrode **401** and the coating member **7** may not be strong enough. On the other hand, in the case that the metal lumps **6** contain Cu, the bond between the first electrode **401** and the metal lumps **6** and the bond between the metal lumps **6** and the coating member **7** are stronger than the bond between the first electrode **401** and the coating member **7**. Hence, the separation of the coating member **7** from the first electrode **401** can be suppressed.

[0091] As shown in FIG. **9**, in the present embodiment, the coating member **7** includes a portion wedged between the first electrode **401** (the bulging section **4013**) and the first face **61** of the metal lump **6**. In other word, the coating member **7** includes a portion that surrounds the first face **61** below its largest diameter part. Thus, the separation of the coating member **7** can be further suppressed.

[0092] In the present embodiment, the bonding sections of the first wires **51** are arranged along the outer edge of the first electrode **401**. The metal lumps **6** are arranged inward of the bonding section **511**. Thus, when providing the coating section **7** after forming the first wires **51** and the metal lumps **6**, it is possible to prevent the nozzle for applying the material paste from interfering with the first wires **51**. It is also possible to prevent the material paste of the coating member **7** from unintentionally adhering to the first wires **51**.

[0093] FIGS. **10-19** show variations and other embodiments of the present disclosure. In these figures, elements identical or similar to the above embodiment are labeled with the same symbols as in the above embodiment.

[0094] FIG. **10** shows a first variation of the semiconductor device A**1**. The semiconductor device A**11** of the present variation differs from the above semiconductor device A**1** in the area where the coating member **7** is provided.

[0095] In the present example, the coating member **7** is not in contact with the bonding sections **511** of the first wires **51**, i.e., the coating member **7** is separated from the bonding sections **511** of the first wires **51** as viewed in the z direction. In other word, the bonding sections **511** are covered by the sealing resin **8** instead of the coating member **7**. As with the semiconductor device A**1**, the coating member **7** covers most of the metal lumps **6**.

[0096] In the present variation, the energy absorbed by an active clamp may be further increased. As understood from such a variation, the coating member **7** is not limited to being in contact with the first wires **51**, but it may be in contact with the first electrode **401**.

[0097] FIG. **11** shows a semiconductor device according to the second embodiment of the present disclosure. The semiconductor device A**2** of the present embodiment differs from the above embodiment in that it includes no metal lumps **6**.

[0098] In the present embodiment, the first electrode **401** is not joined with the metal lumps **6** but joined with the bonding sections **511** of the first wires **51**. The contact area between the coating member **7** and the first electrode **401** is greater than that in the semiconductor device A**1**. The coating member **7** may be in contact with or disposed away from the bonding sections **511** of the first wires **51**.

[0099] In the present embodiment, the energy absorbed by an active clamp may be further increased. As understood from the present embodiment, a semiconductor device according to the present disclosure may not include the metal lumps **6**.

[0100] FIGS. **12-14** show a semiconductor device according to the third embodiment of the present disclosure. The semiconductor device A**3** of the present embodiment differs from the above semiconductor device in the relationships among the first electrode **401**, the first wires **51**, the metal lumps **6**, and the coating member **7**.

[0101] In the present embodiment, the coating member **7** is interposed between the first electrode **401** and both of the metal lumps **6** and the bonding sections **511** of the first wires **51**. In other word, the metal lumps **6** and the bonding sections **511** of the first wires **51** are provided on the coating member **7**, and they are not in contact with the first electrode **401**. The first wires **51** and the metal lumps **6** electrically conduct to the first electrode **401** through the coating member **7**.

[0102] In the present embodiment, the bonding process of the first wires **51** and the formation of the metal lumps **6** may be performed after forming the coating member **7** on the first electrode **401**.

[0103] In the present embodiment, the energy absorbed by an active clamp may be further increased. As understood from the present embodiment, the bonding sections **511** and the metal lumps **6** are not limited to being covered by the coating member **7**, but they may be provided on the coating member **7**.

[0104] In other embodiments below, the configurations of the bonding sections **511**, the metal lumps **6** and the coating member **7** in the semiconductor devices A**1**, A**11**, A**2**, and A**3** may be adopted in any suitable combination.

[0105] FIGS. **15-16** show a semiconductor device according to the fourth embodiment of the present disclosure. The semiconductor device A**4** of the present embodiment differs from the above semiconductor devices in the configurations of the semiconductor element **4** and in that it includes a semiconductor element **42** and a plurality of third wires **53**.

[0106] The semiconductor element **4** in the present embodiment includes the switching part **408**, which performs switching, as in the above semiconductor devices, but does not include the control section **48**.

[0107] The semiconductor element **42** has functions such as controlling, monitoring, and protecting the semiconductor element **4**. The semiconductor element **4** and the semiconductor element **42** are each disposed on the die pad obverse surface **111** of the die pad section **11** via a bonding member **49**. In the illustrated example, the semiconductor element **4** and the semiconductor element **42** are arranged side by side in the y direction.

[0108] The semiconductor element **42** includes a plurality of electrodes **421** and a plurality of electrodes **422**. In the z direction, the electrodes **421** and the electrodes **422** are disposed in the same side. In the illustrated example, in the y direction, the electrodes **421** are disposed at the location closer to the semiconductor element **4**. In the y direction, the electrodes **422** are disposed at the location closer to the third leads **3**. The electrodes **422** include electrodes **4221**, **4222**, **4223**, **4224**. The electrode **4221** corresponds to the third electrode **4031** in the above semiconductor device A**1**. The electrode **4222** corresponds to the third electrode **4032** in the above semiconductor device A**1**. The electrode **4223** corresponds to the third electrode **4033** in the above semiconductor device A**1**. The electrode **4224** corresponds to the third electrode **4034** in the above semiconductor device A**1**.

[0109] In the present embodiment, the second wires **52** are individually connected to the electrodes **422** of the semiconductor element **42** and the third leads **3**. In each wire, the bonding section **521** is joined to the electrode **422**, and the bonding section **522** is joined to the pad section **31** of the third lead **3**.

[0110] The semiconductor device A**4** includes the third wires **53**. The third wires **53** are individually connected to the third electrodes **403** of the semiconductor element **4** and the electrodes **421** of the semiconductor element **42**. Each third wire **53** may include the bonding section **531**, the bonding section **532**, and the loop section **533** as with the second wire **52**. In each wire, the bonding section **531** is joined to the third electrode **403**, and the bonding section **532** is joined to the electrode **421**.

[0111] In the present embodiment, the energy absorbed by an active clamp may be further increased. As understood from the present embodiment, the structure of the semiconductor element **4** is not limited. The die pad section **11** may support not only the semiconductor element **4** but also other semiconductor elements in addition to the semiconductor element **4**, such as the semiconductor element **42**. Moreover, the function of the semiconductor element other than the semiconductor element **4** is not limited.

[0112] FIGS. **17** and **18** show a semiconductor device according to the fifth embodiment of the present disclosure. The semiconductor device A**5** of the present embodiment includes the semiconductor element **4** and the semiconductor element **42** as with the semiconductor device A**4**.

[0113] In the present embodiment, the semiconductor element **42** is disposed on the element obverse face **40***a* of the semiconductor element **4**. Specifically, the semiconductor element **42** is located opposite to the die pad section **11** with respect to the semiconductor element **4** in the z direction. The semiconductor element **42** and the semiconductor element **4** overlap with each other.

[0114] The semiconductor element **42** is joined to the element obverse face **40***a* of the semiconductor element **4** e.g., via the bonding member **49**. In the illustrated example, as viewed in the z direction, the semiconductor element **42** is disposed at the location spaced apart from the first electrode **401** in the y direction. Unlike the illustrated example, the semiconductor element **42** may be disposed on the first electrode **401**.

[0115] In the illustrated example, the first electrode **401** and the semiconductor element **42** each have a long rectangular shape whose longitudinal direction is the x direction. The third electrodes **403** are located between the first

electrode **401** and the semiconductor element **42** in the y direction, and are located side by side in the x direction.

[0116] In the present embodiment, the energy absorbed by an active clamp may be also increased. As understood from the present embodiment, the position and the mounting configuration of the semiconductor element **42** are not limited.

[0117] FIG. **19** shows a first variation of the semiconductor device A**5**. The semiconductor device A**51** of the present variation differs from the above semiconductor device A**5** in the specific configurations of the semiconductor element **4** and the semiconductor element **42**. FIG. **19** partially shows the semiconductor device A**51**, i.e., the area where the semiconductor element **4**, the semiconductor element **42**, and a part of the die pad section **11** are located, with the sealing resin **8** omitted.

[0118] In the present example, the semiconductor element **42** is disposed on the element obverse face **40***a* of the semiconductor element **4**. The semiconductor element **42** is disposed side by side with the first electrode **401** in the x direction.

[0119] The first wires **51** of the present example are provided by a wedge bonding method, for example. Each bonding section **511** extends in the y direction. The bonding sections **511** are arranged side by side in the x direction.

[0120] The semiconductor element **42** has a long rectangular shape whose longitudinal direction is the y direction. The third electrodes **403** of the semiconductor element **4** are located in one side of the y direction with respect to the semiconductor element **42**, and are located side by side with each other in the x direction.

[0121] In such a variation, the energy absorbed by an active clamp may be also increased. As understood from such a variation, the position and the mounting configuration of the semiconductor element **42** are not limited.

[0122] The semiconductor devices according to the present disclosure are not limited to the embodiments described above. The specific configuration of each part of a semiconductor device according to the present disclosure may suitably be designed and changed in various manners. The present disclosure includes the embodiments described in the following clauses.

[0123] Clause 1. A semiconductor device comprising:

[0124] a semiconductor element including a first electrode;

[0125] a sealing resin covering the semiconductor element; and

[0126] a coating member;

[0127] wherein the coating member is interposed between the first electrode and the sealing resin, and contains a material with higher thermal conductivity than the sealing resin.

[0128] Clause 2. The semiconductor device according to clause 1, wherein the coating member contains a metal.

[0129] Clause 3. The semiconductor device according to clause 2, wherein the coating member contains Ag or Cu.

[0130] Clause 4. The semiconductor device according to clause 3, wherein the coating member contains sintered Ag or sintered Cu.

[0131] Clause 5. The semiconductor device according to any of clauses 1 to 4, wherein the first electrode contains Al.

[0132] Clause 6. The semiconductor device according to any of clauses 1 to 5, further comprising at least one first wire including a bonding section joined to the first electrode.

[0133] Clause 7. The semiconductor device according to clause 6, wherein the at least one first wire includes a plurality of first wires, and the bonding sections of the plurality of first wires are disposed along an outer edge of the first electrode.

[0134] Clause 8. The semiconductor device according to clause 7, wherein the coating member is disposed at an area surrounded by the bonding sections of the plurality of first wires.

[0135] Clause 9. The semiconductor device according to any of clauses 6 to 8, wherein each first wire contains a metal different from a metal contained in the first electrode.

[0136] Clause 10. The semiconductor device according to any of clauses 6 to 9, wherein each first wire contains Cu.

[0137] Clause 11. The semiconductor device according to any of clauses 6 to 10, wherein the coating member is in contact with the bonding section of each first wire.

[0138] Clause 12. The semiconductor device according to any of clauses 6 to 11, further comprising at least one metal lump joined to the first electrode.

[0139] Clause 13. The semiconductor device according to clause 12 wherein the metal lump contains a metal different from a metal contained in the first electrode.

[0140] Clause 14. The semiconductor device according to clause 12 or 13, wherein the coating member is in contact with the metal lump.

[0141] Clause 15. The semiconductor device according to clause 14, wherein the coating member covers the metal lump.

[0142] Clause 16. The semiconductor device according to clause 15 wherein a maximum thickness of the coating member is greater than a thickness of the bonding section of each first wire.

[0143] Clause 17. The semiconductor device according to clause 15 or 16, wherein the coating member includes a periphery and a center portion that is thicker than the periphery.

[0144] Clause 18. The semiconductor device according to any of clauses 15 to 17, wherein the maximum thickness of the coating member is at least 20 μm.

[0145] Clause 19. The semiconductor device according to any of clauses 15 to 17, wherein the maximum thickness of the coating member is at least 80 μm.

[0146] Clause 20. The semiconductor device according to any of clauses 15 to 17, wherein the maximum thickness of the coating member is at least 160 μm.

[0147] Clause 21. The semiconductor device according to any of clauses 15 to 20, wherein the metal lump is disposed opposite to the outer edge of the first electrode with respect to the bonding section of each first wire.

[0148] Clause 22. The semiconductor device according to clause 21, wherein each first wire has a loop section connected to the bonding section, and

[0149] the loop section extends outwardly of the semiconductor element and intersects the outer edge of the first electrode in plan view.

[0150] Clause 23. The semiconductor device according to any of clauses 15 to 22, wherein the metal lump includes a first face facing the first electrode and being inclined so as to be located further away from a center of the metal lump as proceeding further away from the first electrode,

[0151] the coating member includes a portion between the first electrode and the first face.

[0152] Clause 24. The semiconductor device according to any of clauses 1 to 23, wherein the semiconductor element includes a switching section to perform switching and a control section to control the switching section, and

[0153] the first electrode is an electrode of the switching section.

[0154] Clause 25. The semiconductor device according to clause 24, wherein the first electrode is a source electrode.

REFERENCE NUMERALS		
A1, A11, A2, A3, A4, A5, A51: Semiconductor device		
1: First lead	2: Second lead	3: Third lead
4: Semiconductor element	6: Metal lump	7: Coating member
8: Sealing resin	11: Die pad section	12: Extending section
21: Pad section	22: Terminal section	31: Pad section
32: Terminal section	40: Element body	
40a: Element obverse face	40b: Element reverse face	
42: Semiconductor element	48: Control section	
49: Bonding member	51: First wire	52: Second wire
53: Third wire	61: First face	62: Second face
63: Projection	81: Resin obverse face	
82: Resin reverse face	83: First resin side face	
84: Second resin side face	111: Die pad obverse face	
112: Die pad reverse face	401: First electrode	
402: Second electrode		
403, 4031, 4032, 4033, 4034: Third electrode		
408: Switching section		
421, 422, 4221, 4222, 4223, 4224: Electrode		
511, 512, 521, 522, 531, 532: Bonding section		
513, 523, 533: Loop section	4011: Base thickness section	
4012: Reduced thickness section	4013: Bulging section	
5111: First face	5112: Second face	

1. A semiconductor device comprising:

a semiconductor element including a first electrode;

a sealing resin covering the semiconductor element; and

a coating member;

wherein the coating member is interposed between the first electrode and the sealing resin, and contains a material with higher thermal conductivity than the sealing resin.

2. The semiconductor device according to claim **1**, wherein the coating member contains a metal.

3. The semiconductor device according to claim **2**, wherein the coating member contains Ag or Cu.

4. The semiconductor device according to claim **3**, wherein the coating member contains sintered Ag or sintered Cu.

5. The semiconductor device according to claim **1**, wherein the first electrode contains Al.

6. The semiconductor device according to claim **1**, further comprising at least one first wire including a bonding section joined to the first electrode.

7. The semiconductor device according to claim **6**, wherein the at least one first wire includes a plurality of first wires, and

the bonding sections of the plurality of first wires are disposed along an outer edge of the first electrode.

8. The semiconductor device according to claim **7**, wherein the coating member is disposed at an area surrounded by the bonding sections of the plurality of first wires.

9. The semiconductor device according to claim **6**, wherein each first wire contains a metal different from a metal contained in the first electrode.

10. The semiconductor device according to claim **6**, wherein each first wire contains Cu.

11. The semiconductor device according to claim **6**, wherein the coating member is in contact with the bonding section of each first wire.

12. The semiconductor device according to claim **6**, wherein further comprising at least one metal lump joined to the first electrode.

13. The semiconductor device according to claim **12** wherein the metal lump contains a metal different from a metal contained in the first electrode.

14. The semiconductor device according to claim **12**, wherein the coating member is in contact with the metal lump.

15. The semiconductor device according to claim **14**, wherein the coating member covers the metal lump.

16. The semiconductor device according to claim **15** wherein a maximum thickness of the coating member is greater than a thickness of the bonding section of each first wire.

17. The semiconductor device according to claim **15**, wherein the coating member includes a periphery and a center portion that is thicker than the periphery.

18. The semiconductor device according to claim **15**, wherein the maximum thickness of the coating member is at least 20 μm.

19. The semiconductor device according to claim **15**, wherein the maximum thickness of the coating member is at least 80 μm.

20. The semiconductor device according to claim **15**, wherein the maximum thickness of the coating member is at least 160 μm.

* * * * *